Geochemical and Microbiological Investigations of Sediment Cores and Formation Waters for CO₂ Sequestration in Deep Arbuckle Saline Aquifer, South-Central Kansas

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Introduction

- Arbuckle aquifer in SC Kansas has been targeted for this CO₂ sequestration project as a way to mitigate future release of this greenhouse gas
- Deep saline aquifers are one of the most appealing geologic formations for sequestration because they are unfit for drinking and usually isolated from fresh water sources
- Secure, long term storage involves mineralization reactions that require the presence of certain minerals and ionic species to facilitate precipitation reactions
- 1600 feet of core was taken from well KGS 1-32 for mineralogical description and formation core samples have been analyzed by X-ray diffraction, thin section and electron micrograph
- Water samples have been collected from 8 drill stem tests (DST) (6077', 4182', 4335', 4520', 4876', 4927', 5036') and 1 swab test (5010') in the Mississippi and Arbuckle aquifers and analyzed for detailed hydrogeochemistry and microbiological geochemistry

Hydrogeochemistry and Microbiological Geochemistry

- Elemental ratios of closely associated species. Correlation between these species is high, typical of a saline aquifer system. Linear correlation indicates Arbuckle is a single, connected system
- Total dissolved solids for the 6 DST samples within the Arbuckle increase with depth
- Formation and Caprock Mineralogy
- The Arbuckle is lower part of the Quauch Plaquon Aquifer System which includes the freshwater Ogallala aquifer
- Salinity values in the aquifer range from 30,000 to 120,000 ppm
- Arbuckle Group rocks are late Cambrian to early Ordovician in age consisting generally of porous dolomitic carbonates with interbedded shale-y shaly sandstones
- The Arbuckle is overlain by the Simpson sandstone and the Cherokee shale (absent in KGS 1-32, present in 1-28)
- Two wells (KGS 1-32 and 1-28) were drilled 3000 ft apart in the Wellington field, Sumner Co, SC Kansas (figure 1)
- The wells extend through the entire Arbuckle formation and into the Precambrian granite bedrock below (figure 2)

Supercritical Flow Experiments

- National Energy Technology Laboratory, Pittsburgh, PA Core-flow laboratory, August 30, 2012
- Core Flow System lab instrument was used to flow brine and CO₂ through formation core
- Core from the injection zone was used at 30 °C to simulate the geology and core processing at NETL
- Core flow experiments were run at 0.2 mL/min for 13 hours to saturate core
- CO₂ was introduced with brine at 1:1 ratio
- Efficient collected hourly for analysis (hour 14 is an average of overnight brine/CO₂ flow)

Conclusions and Future Work

- The hydrogeochemical facies in the Arbuckle is mostly Na-Ca-Cl type with high salinity and showing an increasing trend with depth. Average salinity of the injection zone formation water of the core at 156,000 ppm Cl⁻ indicates more dissolution of these ions
- Robust microbial communities were found including methanogenic, iron reducing and sulfate reducing bacteria
- High organic carbon at certain depths indicate high biomass that might affect geochemical reactions during CO₂ injection
- Mineralogical description of core recovered from KGS 1-32 show extensive small and large scale heterogeneity with major mineralogy being dominated by dolomite: limestone with frequent sandy zones and infillings. Microfractures and discontinuous argillaceous zones where marked all through the 1600 ft core. Core size analysis of different core plugs may be relevant for increased precipitation. Supporting evidence can be found in line flow experiments where 13-24 hours showed decreases in Ca, Mg, Na and SO₄ which could be due to mineral precipitation.

References


Figure 1: Contour map of the Arbuckle group in Kansas and regional study 6-25,000 sq. miles

Figure 2: Well log of the Arbuckle and Mississippian aquifers from KGS 1-32 experimental well, Sumner Co, KS. Two shale aquifers have been identified in the Arbuckle that could act as a barrier to CO₂ flow. Directly above the Arbuckle is the Simpson sandstone and the Chautauqua shale which acts as a cap rock. Total depth in KGS 1-32 is ~5200 ft

Figure 3: Time series (24 hour) analysis for CO₂-brine flow-through experiment. Core is a dolostone, highly porous coarse grained dolostone; matrix is poorly connected, coarse grain dolomite with 20% of all one plug

Figure 4: Evidence of microbial metabolism from aqueous geochemistry: DOC and PO₄ are in excess to supply Ca at 60°F. Higher bicarbonate may be required for bacterial growth, and bacterial production may be responsible for the pH reduction.

Figure 5: Evidence of microbial metabolism from aqueous geochemistry: SEM images of the core plugs show clear interface between chert and dolomite where fractures and chert with possible secondary calcite. NETL flow through experiment. Core is autoclastic dolomite, pore space is open and is connected.

Figure 6: Time series of core plug 31-19 flow-through experiment at NETL. White areas are dense 

Figure 7: Total dissolved solids for the 6 DST samples within the Arbuckle increase with depth

Figure 8: Total dissolved solids in Arbuckle

Figure 9: Before flow After flow...